Survival estimates and tailrace egress of yearling Chinook salmon through The Dalles Dam spillway using radiotelemetry, 2006.

Final Report of Research

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Contract No. W66QKZ50458618

Submitted: November 1, 2007

Executive Summary

During 2006, the U. S. Geological Survey evaluated the passage, survival, and tailrace egress of yearling Chinook salmon at The Dalles Dam spillway to assess the efficacy of recent spillway modifications. Our objectives were to evaluate single-release model survival estimates and characterize tailrace egress for radio-tagged yearling Chinook that passed through spill bays 1-4 or 5-6. At The Dalles Dam during 2006, the estimated survival of radio-tagged yearling Chinook salmon passing through spill bays 1-4 (S = 0.946, SE = 0.010, 95% confidence interval = 0.922 - 0.969) was significantly higher ($t(14)$ = 1.87, P<0.05) than the estimated survival of fish passing spill bays 5-6 (S = 0.906, SE = 0.019, 95% confidence interval = 0.863 - 0.949). To make 2006 estimates more comparable to past years, 2004 and 2005 data were re-analyzed using the single release-recapture model design in program MARK. Survival estimates for 2006 were very similar to 2005, whereas 2004 estimates were relatively low. During 2005, the estimated survival of yearling Chinook salmon using the single release model for spill bays 1-4 was S = 0.956 (SE = 0.014, 95% confidence interval = 0.926 - 0.986) and for spill bays 5-6, S = 0.904 (SE = 0.011, 95% confidence interval = 0.880 - 0.928). During 2004, the estimated survival of yearling Chinook salmon using the single release model for spill bays 1-4 was S = 0.910 (SE = 0.012, 95% confidence interval = 0.885 - 0.935) and for spill bays 5-6, S = 0.859 (SE = 0.014, 95% confidence interval = 0.829 - 0.888).

Radio-tagged yearling Chinook salmon that passed through spill bays 1-4 had significantly faster travel times (P<0.0001) to the Basin Island exit site, 1.7 km downstream, than fish that passed through bays 5-6. The median travel time of fish that passed through spill bays 1-4 (10.6 min) was 30% faster than the median travel time of fish that passed through spill bays 5-6 (15.1 min). Of the fish detected for greater than 5 minutes at an eddy located along the navigation lock wall, 42.1% passed through spill bays 1-4 and 57.9% passed through spill bays 5-6. The median residence time in the eddy for fish that passed through spill bays 1-4 (6.8 min) was significantly shorter than for fish that passed through spill bays 5-6 (8.5 min; P = 0.001). Arrays monitoring the stilling basin south of the spillwall detected 7% of the radio-tagged fish that passed through spill bays 1-6. The majority (68%) of these fish passed through spill bays 5-6. The median residence time south of the spillwall for fish that passed through spill bays 1-4 (1.5 min) was significantly shorter than for fish that passed through spill bays 5-6 (5.4 min; P = 0.002).

Acknowledgements

We thank Mike Langeslay, Brad Eppard, Miroslaw Zyndol and other personnel at the U.S. Army Corps of Engineers for their assistance in administering our contract and assisting with the logistics involved with coordinating this research at The Dalles Dam. Many thanks to Greg Kovalchuk of the Pacific States Marine Fisheries Commission, and the entire John Day Dam Smolt Monitoring Facility staff for sorting and collecting our research fish. This work would not have been possible without the field efforts and technical assistance of Sarah Breeze, Tim Counihan, Isreal Duran, Theresa Liedtke, Jacque Schei, Ryan Tomka, Erin Wright and several of our other colleagues at the Columbia River Research Laboratory. We thank several reviewers for providing peer review comments. We would also like to acknowledge the assistance of the administrative staff at the Columbia River Research Laboratory for their support in managing the contracts for this research. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the United States Department of Interior or the United States Geological Survey of any product or service to the exclusion of others that may be suitable.

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Introduction

Survival of salmonid smolts through The Dalles Dam is typically lower than at other projects on the lower Columbia River (Ploskey et al. 2001). In recent years various spill levels, spill configurations, and dam modifications have been implemented at The Dalles Dam to increase the survival of outmigrating smolts. Lower than expected spillway survival probabilities at The Dalles Dam are thought to be due to: 1) predation; spillway-passed water moves through areas where predation on salmonids by gulls (*Larus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), and smallmouth bass (*Micropterus dolomieu*) likely occurs, and 2) a short stilling basin and shallow tailrace, resulting in severe turbulence and lateral currents that may cause physical injury to migrant salmon. To prevent lateral currents in the stilling basin a concrete spillwall was constructed during the winter of 2002-03 that extended the pier nose between bays 6 and 7 to the end sill. Spill operations were changed to target 40% spill through spill bays 1-6. The intent of these modifications was to increase the survival of juvenile salmonids that pass through the spillway.

The efficacy of these spillway modifications was evaluated in 2004 and 2005. Studies using balloon tags at The Dalles Dam spillway in 2004 found that survival estimates were higher and passage related maladies were lower for yearling Chinook salmon passing spill bays 2 and 4 than for spill bay 6 (Normandeau Associates, Inc. and Skalski 2005). Data from USGS radiotelemetry survival evaluations of yearling and subyearling Chinook salmon passing the spillway at The Dalles Dam in 2004 and 2005 suggested that survival estimates were higher and egress times were shorter for fish passing bays 1-4 than through bays 5-6 (Counihan et al. 2006a, 2006b, Daniel et al. 2006). A radiotelemetry study looking at fish passage distribution in 2005 found that 78% of yearling Chinook salmon passed The Dalles Dam via the spillway, and of the spillway passed fish, 64% went through bays 5-6 (Hansel et al. 2007). This passage distribution is reason for concern due to the lower survival of fish passing bays 5-6 relative to bays 1-4.

The results from the spillway survival studies raised concerns that tailrace conditions were contributing to reduced survival of spillway passed fish. Specifically, the possibility that additional slow water habitat favoring salmonid predators was created to the south of the spillwall, where spill bays are infrequently open, resulting in greater predation of fish passing bays 5-6. As well as the continuing concern that fish passing bays 5-6 are traveling further south in the river through shallow waters and along islands during tailrace egress and are more likely to be exposed to predators such as northern pikeminnow and smallmouth bass. In 2006 the USGS estimated the survival and egress of yearling Chinook salmon through spill bays 1-4 and 5-6 to help better understand where mortality is occurring and thus focus future efforts to improve survival.

Methods

Study area

To estimate spillway survival and characterize tailrace egress of yearling Chinook salmon at The Dalles Dam during the 2006 spring out migration, we monitored radio-tagged fish released in the forebay upstream of The Dalles Dam spillway. The study area (e.g., zone of inference; Peven et al. 2005) extended from The Dalles Dam forebay downriver to Bridge of the Gods (Figure 1). Antenna arrays within the study area were located on The Dalles Dam (River kilometer (RK) 308.1), at the basin island (RK 306.4), at Chamberlain Lake Rest Area (RK 286.1), 18 Mile Island (RK 279.8), near the town of Underwood, WA on the bluff (RK 270), and on Bridge of the Gods (RK 238.6). All detection arrays spanned the breadth of the river channel.

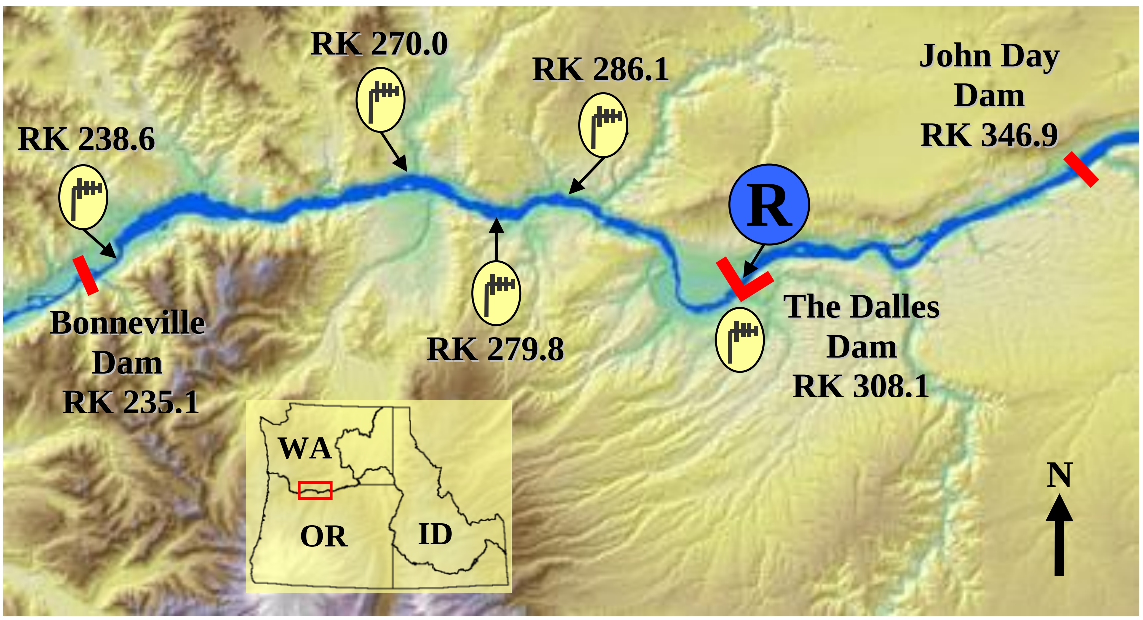

Figure 1. Release and detection locations for The Dalles Dam survival evaluation during 2006. Ovals show locations of radiotelemetry arrays, the polygons represent the dams, and ® indicates release location. River kilometers are given for each location.

The Dalles Dam powerhouse is oriented approximately perpendicular to the natural river thalweg (Figure 2). It is 636.7 m long, containing 22 Kaplan turbine units with a generating capacity of 1.8 million kilowatts. Openings in the dam at the water's surface above each turbine intake allow water and debris to flow into an ice and trash sluiceway. Water and debris flow to an outfall and plunge into the tailrace at the western end of the powerhouse. A non-overflow wall connects the powerhouse and spillway. The spillway consists of 23 spill bays each controlled by a tainter gate. The spillway was modified during the winter of 2003 by adding a spillwall that extends from the tailrace pier nose between bays 6 and 7 to the end sill. A navigation lock is located at the northwest end of the dam. The dam has two adult fish ladders, one between the spillway and navigational lock, the other at the east end of the powerhouse.

Figure 2. Aerial view of The Dalles Dam looking upriver (northeast).

Radiotelemetry system

The radiotelemetry antenna arrays at The Dalles Dam used to monitor movements and passage location of radio-tagged fish consisted of 4-element Yagi aerial antennas and dipole underwater antennas. On the spillway there were 12 aerial antennas on the forebay side and 13 aerial antennas on the tailrace side; each aerial antenna was directed 45° away from the dam and provided coverage for two adjacent bays. A total of 90 underwater antennas were attached to the spillway forebay pier noses. The detection range for aerial antennas can be as much as 100 m from the dam, but varies with the depth of the transmitter in the water column. The detection range for underwater antennas was 10 m. Antennas were connected to either an SRX-400 data logging telemetry receiver (Lotek Wireless, Newmarket, Ontario, Canada), or a Multiprotocol Integrated Telemetry Acquisition System (MITAS; Grant Systems Engineering, King City, Ontario, Canada). Data logging devices stored detection records for individual transmitter channel codes; data were downloaded to a laptop computer daily.

Fish were tagged with pulse-coded radio transmitters manufactured by Lotek Engineering, Inc. (Newmarket, Ontario, Canada). Transmitters implanted in yearling

Chinook salmon weighed approximately 0.64 g in air, were 6.3 mm wide by 14.5 mm long, and had a 16 cm long antenna (Lotek Wireless model NTC-3-1). Transmitters operated at frequencies between 150.350 and 150.740 MHz and used a pulse-coding scheme with 521 unique codes per frequency that allow each individual fish to be recognized. NTC-3-1 transmitters emitted radio signals every 2 s; at this pulse rate the expected battery life was 10 d.

Fish tagging and release

Yearling Chinook salmon were collected from the juvenile collection and bypass facility at John Day Dam, transported to The Dalles Dam, and held approximately 12 to 36 h prior to tagging. Fish were considered suitable for tagging if they were free of recent injuries, severe descaling, external signs of gas bubble trauma, and other diseases and abnormalities, and met the minimum weight criterion. To minimize the impact of the tag, a fish size criterion was established so that the radio-tag weight in air would not exceed 5% of a fish's weight in air. The minimum weight for a yearling Chinook salmon implanted with a Lotek Wireless model NTC-3-1 tag was 14.5 g. Transmitters were surgically implanted using the methods of Adams et al. (1998). After tagging, fish were held for approximately 18 to 28 h in perforated 19 L buckets (2 fish per bucket), in large, insulated, metal tanks supplied with flow-through river water. After the holding period, any dead fish were removed. In 2006, four tagged fish died during the recovery period (Releases 2, 17, 18, and 61 each had one fish die). Throughout tag and release procedures, water quality parameters (temperature, dissolved oxygen, and total dissolved gas) were monitored to assure proper conditions for holding and transporting fish.

From 3 May to 2 June, 1,180 radio-tagged yearling Chinook salmon were released for the survival and egress evaluation (Appendix 1; Table A1.1). Fish were released from a boat into The Dalles Dam forebay approximately 200 m upstream of the dam. On each release date, two consecutive releases were made into the forebay to try to balance the numbers of fish passing the north spillway (bays 1-4) and the south spillway (bays 5-6). For north spillway releases the boat was positioned in the center of bay 4. For south spillway releases the boat was positioned in front of spill bay 16. Releases were made at approximately 0100, 0700, 1300, or 1900 hours (Appendix 1; Table A1.1). Releases were randomized and equally allocated among the four release times. Release times were the midpoints of 6-h blocks of divergent discharge conditions observed at The Dalles Dam in diel discharge patterns.

To assess how well tagged fish represented the in-river fish population, we obtained fork length data for run-of-river fish sampled at the John Day Dam smolt monitoring facility and compared them to fork length data for radio-tagged fish. To examine the timing of the study relative to the run timing of run-of-river fish, we obtained passage index data from the Fish Passage Center (see: www.fpc.org). The passage index is the number of fish sampled divided by the sample rate divided by the proportion of water passing through the sampling system.

Converting radio signals into detection histories

After data collection, radio signals were interpreted and converted into detection histories. Aerial and underwater antennas attached to data logging equipment will often record spurious radio signals or "noise" and designate them as such, or misinterpret other radio signals (e.g., from cars or trucks) and label them with fish channel and code designations. We performed automated data processing using Statistical Analysis System (SAS) software to separate spurious radio signals from true radio signals and assign passage and location designators. The following criteria were used to classify data records as noise:

1. Records composed of invalid channel and code combinations, typically a result of erroneous radio transmissions (noise) that overlap with the radio frequencies we were monitoring.
2. Records logged before a fish's release.
3. Records logged 10 or more days after a fish's release (the estimated battery life of the tag).
4. Records below an empirically determined signal strength threshold for each aerial and underwater array.
5. Fewer than two records recorded within a 20 min period for an individual fish.

Once all times and locations of interest (events) were electronically assigned, the program flagged suspect records for manual proofing based on travel time, residence time, and geographic criteria. Travel times were calculated as the elapsed time between the first detection at one array and the first detection at all subsequent downstream arrays. Residence time was calculated as the elapsed time between the first and last detection at each geographic area. For travel time and residence time criteria, we estimated the probability of travel or residence time for each fish at, or between, each location. To estimate this probability, we fit the cumulative inverse Gaussian distribution to the observed travel time distributions (Zabel 1994; Zabel et al. 1997). If the probability of travel time or residence time for a fish was ≤ 0.005 or ≥ 0.995, the records were flagged for manual proofing. The travel time criterion was effective in identifying noise records that passed other criteria. The geographic criterion flagged records for manual proofing if there were spatiotemporal inconsistencies. For example, detections at the dam after a fish was detected at a downstream array were flagged. Fish whose event histories were flagged because of one or more of the above criteria were manually proofed. In addition to the flagged files, a random 10% of the fish from non-flagged files were manually examined to ensure the automatic proofing criteria removed invalid detections, retained valid detections, and correctly assigned events. The complete detection history of each manually proofed fish was inspected twice by separate individuals, and a third individual reconciled any differences in the electronically assigned events and the manually assigned events.

Fish were assigned passage through spill bays based on interrogations from underwater antennas at the spillway. Because the number of fish passing through an individual spill bay from an individual release was often low, spill bays and releases were combined to improve the precision of estimates. Fish were assigned passage through spill bays 1-4 or 5-6. After assigning fish to spill bay groupings, releases were temporally combined into 4-d blocks (Appendix 1; Table A1.2).

Single release-recapture survival model

We used the single release-recapture model developed by Cormack (1964), Jolly (1965), and Seber (1965; CJS model) to estimate survival probabilities. The single release-recapture model requires as a minimum the following design elements: that tagged fish are uniquely identifiable, at least two downstream detection sites below the release locations, the re-release of all or some of the marked fish recaptured at each detection location, and the recording of the identity of the marked fish recaptured at each location (Peven et al. 2005). John Skalski (University of Washington) in Peven et al. (2005) provides a discussion of the potential bias associated with this methodology.

Survival can be estimated from the release point to the next detection array, and from then on, survival is estimated from the detection zone of one detection array to the next (Figure 3). Unique recapture probabilities can be estimated at each detection array except the farthest downstream. In the last reach, only the joint probability of survival to and detection at the last array can be estimated (i.e., $\lambda = S \bullet p$). Thus, the minimal study design must consist of at least two downstream detection locations.

The assumptions of the single release-recapture model are the following:

A1. Individuals marked for the study are a representative sample from the population of interest.

A2. Survival and recapture probabilities are not affected by tagging or sampling. That is, tagged animals have the same probabilities as untagged animals.

A3. All sampling events are "instantaneous." That is, sampling occurs over a negligible distance relative to the length of the intervals between sampling locations.

A4. The fate of each tagged individual is independent of the fate of all others.

A5. All tagged individuals alive at a sampling location have the same probability of surviving to the next sampling location.

A6. All tagged individuals alive at a sampling location have the same probability of being detected at that location.

A7. All tags are correctly identified and the status of each smolt (i.e., alive or dead), correctly assessed.

The first assumption (A1) involves inferences from the sample taken to the target population. For example, if inferences are desired for yearling Chinook salmon, then the sample of tagged fish should be drawn from that population. These assumptions could also be violated if the fish selected for tagging were on average larger than the target population.

Assumption (A2) again concerns making inferences to the target population (i.e., untagged fish). If tagging has a detrimental effect on survival, then survival estimates from the single release-recapture design will tend to be negatively biased.

The third assumption (A3) stipulates that mortality is negligible immediately near the sampling stations, so that the estimated mortality is associated with the river reaches and not the sampling event. For migrant salmonids, the time spent near detection equipment is typically brief relative to the time spent in the river reaches.

The assumption of independence (A4) suggests that the survival or death of one smolt has no effect on the fates of others. In the Columbia River where many thousands of migrants can be found, this is likely true. Violations of assumption (A4) may bias the variance estimate (true variability would be greater than estimated).

Assumption (A5) specifies that the prior detection history of the tagged fish does not affect subsequent survival. This assumption could be violated if fish were trained to go through turbine or spill routes or alternatively to avoid routes because of prior experience. The lack of handling following initial release of radio-tagged fish minimizes the risk that subsequent detections influence survival.

Similarly, assumption (A6) could be violated if downstream detections were influenced by upstream passage routes taken by tagged fish. Violation of this assumption is minimized by placing radio telemetry arrays across the breadth of the river and below the mixing zones for fish using different passage routes. Burnham et al. (1987) Tests 2 and 3 can be used to assess overall goodness-of-fit to single release-recapture assumptions, in particular whether upstream capture histories are independent of downstream histories.

Assumption (A7) implies that fish do not lose their tags and are subsequently misidentified as non-detected, or dead fish are falsely recorded as alive at detection locations. Tag loss would result in a negative bias (i.e., underestimation) of fish survival rates. Typically, the retention rate of active transmitters is high suggesting that the effects of tag loss on survival estimates would be minimal. Dead fish drifting downstream could result in false-positive detections and upwardly bias survival estimates. Tailrace antenna arrays are therefore not recommended for survival estimation because they are too close to locations of potential mortality. In addition dead radio-tagged fish were released during the season along with live radio-tagged fish to determine the potential for detecting dead fish.

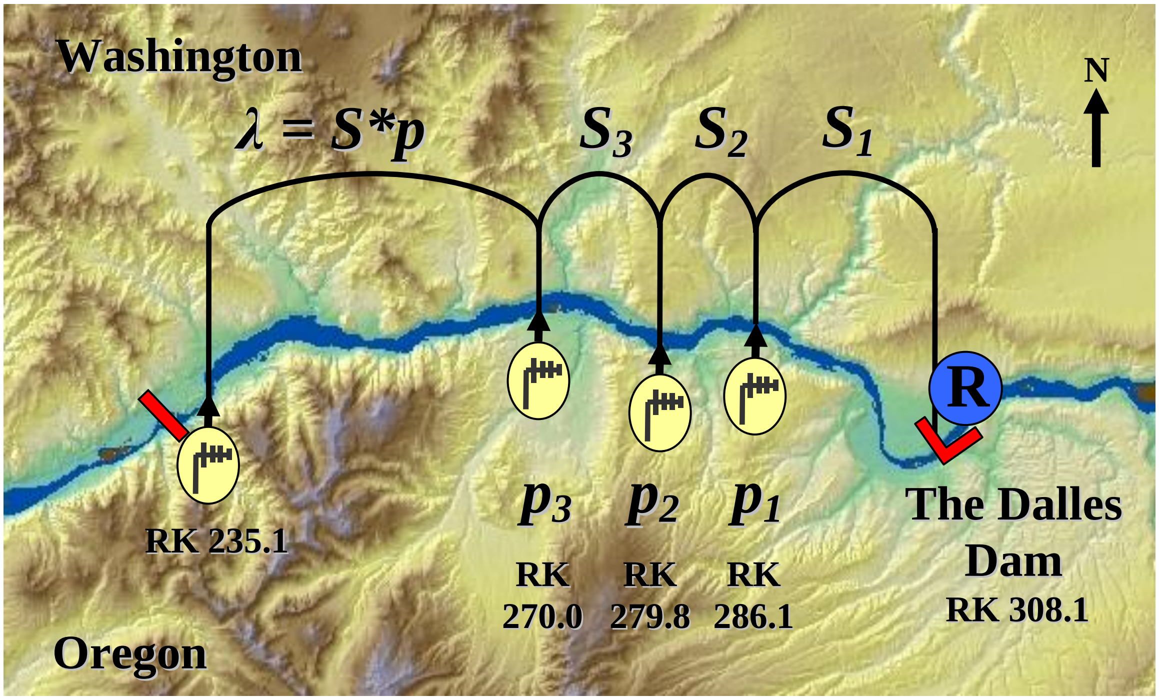

Figure 3. Schematic of release, detection sites, and estimated survival parameters generated in the single release-recapture design to estimate migrant juvenile salmonid survival through the spillway at The Dalles Dam. S = survival estimate, p = capture probability, λ = S · p, ovals = radiotelemetry arrays, polygons = dams. ® represents fish released into the forebay of The Dalles Dam that have been detected at and determined to have passed the The Dalles Dam spillway. River kilometers are given for each location.

Survival estimation

Detection histories of each fish form the basis of the single release model and allow for the estimation of survival and detection probabilities. Program MARK (White and Burnham 1999) was used to estimate single release survival and detection probabilities. To prepare the data for input into MARK, records for each fish were summarized into detection histories to indicate whether a fish was detected at each downstream telemetry array. Each unique detection history has a probability of occurrence that can be specified by: 1) the probability that a fish survived (*S*) through reach *i*, S_i, and 2) the probability of detection (*p*) at array *i*, p_i. The expected probability of each detection history is estimated from the observed frequencies of fish with that detection history. Given the expected probability of each detection history and its probability function in terms of S_i and p_i, maximum likelihood methods were used to find the combination of S_i and p_i that were most likely to occur given the data set of detection histories.

The survival estimates reported are for the river reach extending from The Dalles Dam spillway to the detection site 22 km downstream (S_1, Figure 3). In 2004 and 2005, spillway survival was estimated using the paired release-recapture model (Counihan et al. 2006a, Counihan et al. 2006b). To make 2006 estimates more comparable to past years, 2004 and 2005 data were re-analyzed using the single release-recapture model design in program MARK. In 2004 and 2005, radio-tagged fish were released in the tailrace of John Day Dam and volitionally passed The Dalles Dam. Because the number of fish passing through an individual spill bay from an individual release was often low, spill bays and releases were combined to improve the precision of estimates. Fish were assigned passage through spill bays 1-4 or 5-6 based on interrogations on underwater antennas at the spillway. After assigning fish to spill bay groupings, fish were temporally combined into 2-d blocks based on their passage time. A block started at 18:00 hours and ended 48 hours later at 17:59. The detection sites depicted in Figure 3 were used in forming the detection histories for all three years.

Egress analysis

To characterize tailrace egress, travel times of study fish were calculated from the time fish were last detected on forebay underwater antennas to the time of their last detection at the basin island exit (Figure 4). We present median travel times with ranges and used the Kruskal-Wallis test of medians to compare groups. All findings with $P \leq 0.05$ were considered statistically significant.

Figure 4. The Dalles Dam egress study area, 2006. The basin island exit site, indicated by the blue line, is approximately 1.7 km downstream of the spillway.

Eddy analysis

An eddy occurs approximately 0.5 km downriver of the spillway along the navigation lock wall (Figure 5). A fixed-site receiving station was established at this location to monitor the eddy for radio-tagged fish with extended residence times that might suggest an elevated risk of predation. We analyzed the residence time within the range of this station by limiting the dataset to include only fish detected in this area for more than 5 min. and passing via the north channel. The 5 min criterion is based on knowledge that fish can readily move through the tailrace, downstream of the eddy area, within that time. Detections of fish in the first 5 min after their entrance into the tailrace depict predictable downstream movement and do not suggest egress delay. We present median residence times with ranges for spill bay 1-4 and spill bay 5-6 passage groups and used the Kruskal-Wallis test of medians to make comparisons. All findings with $P \leq 0.05$ were considered statistically significant.

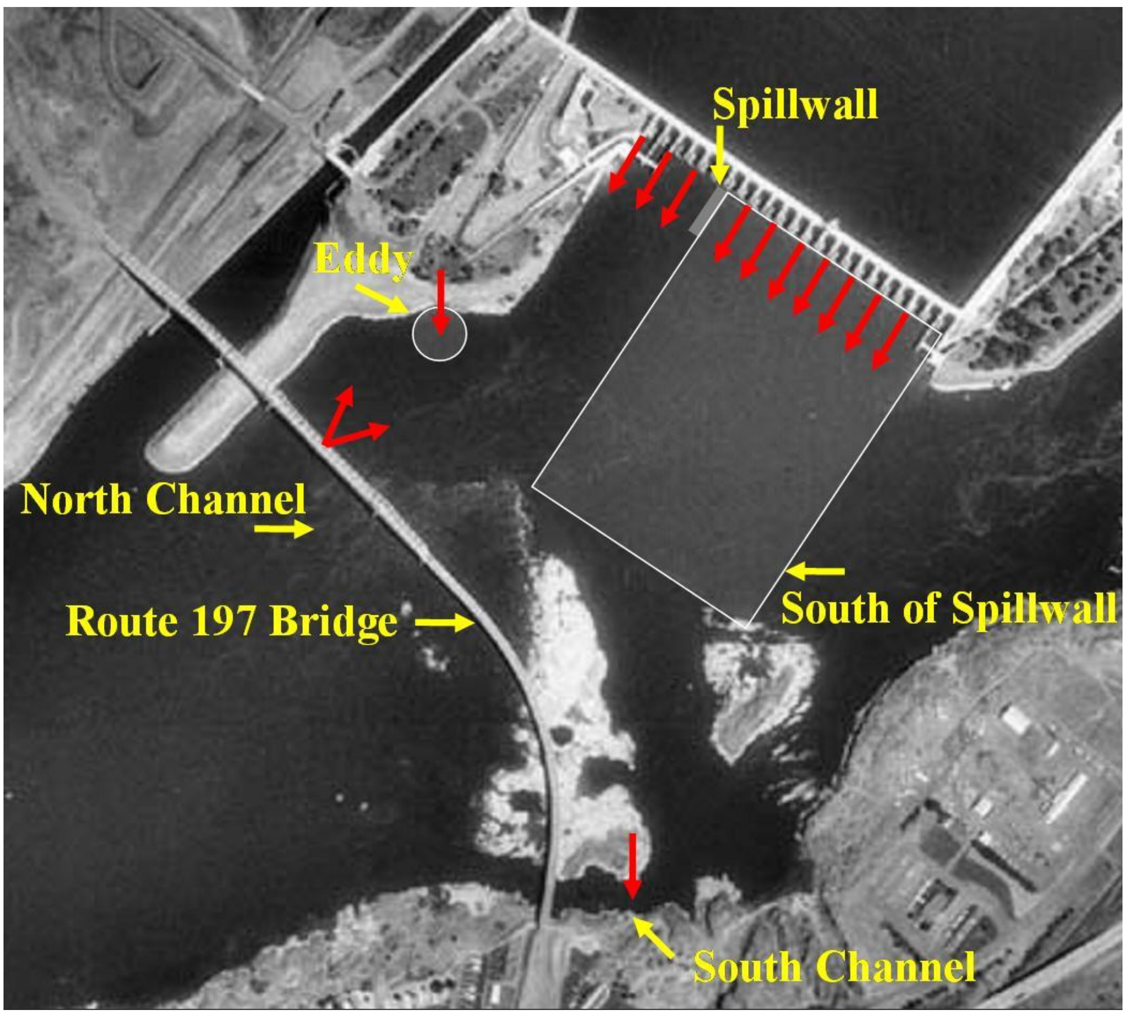

Figure 5. The Dalles Dam tailrace aerial antenna array, 2006. The approximate locations of aerial antenna arrays are indicated by red arrows.

South stilling basin residence time

We used the antenna arrays on the tailrace face of the dam and the Route 197 Bridge (Figure 5) to determine residence time in the stilling basin, south of the spillwall. Residence time was calculated from the last detection in the forebay to the first detection on the Route 197 Bridge array. Only fish that were detected on the tailrace antennas monitoring spill bays south of the spillwall were included.

Results

River conditions and project operations

River conditions and project operations data were obtained from the U.S. Army Corps of Engineers' Technical Management Team website: www.nwd-wc.usace.army.mil/tmt/. During the spring study period (3 May to 2 June) average hourly river temperature in the tailrace ranged from 11.2 to 15.1°C (Figure 6), with a season average of 13.2°C. Average hourly total discharge ranged from 196 thousand cubic feet per second (kcfs) to 409 kcfs (Figure 6), averaging 328 kcfs for the season. Average hourly spill discharge ranged from 78 kcfs to 251 kcfs (Figure 6), averaging 131 kcfs for the season. This resulted in 29-66% (season average: 40%) of the discharge passing through the spillway (Figure 6).

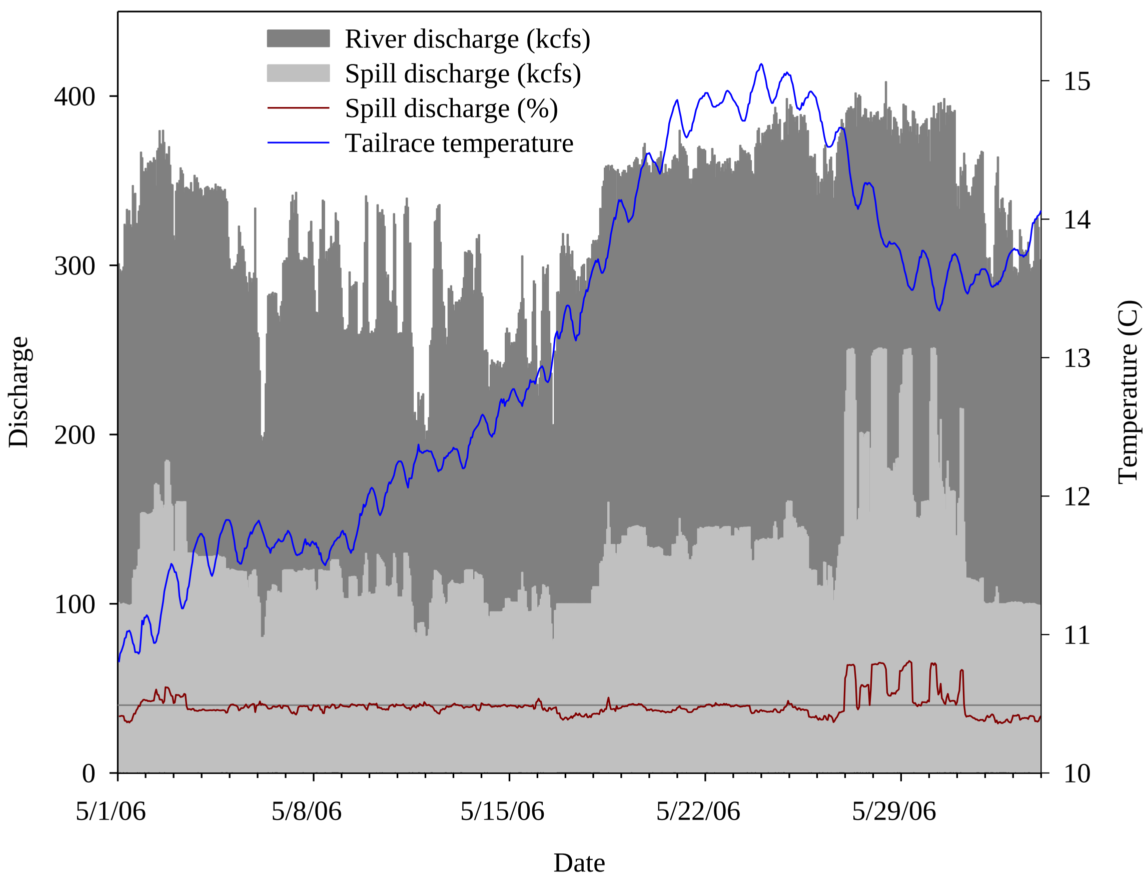

Figure 6. Hourly averages of total discharge (kcfs), spill discharge (kcfs), percent spill discharge, and tailrace temperature (°C) at The Dalles Dam during the spring study period, 2006. The dark gray horizontal line indicates 40% spill, the targeted spill operation.

Tagged fish size and study period relative to run-at-large

The mean length of yearling Chinook salmon at the sampling facility from 3 May to 2 June was 143 mm, while the mean radio-tagged fish length was 147 mm (Figure 7). The range and mean fork lengths and weights for tagged fish by release are reported in Appendix 1. The study period started at approximately the 27th percentile of the run and ended at the 98th percentile (Figure 8).

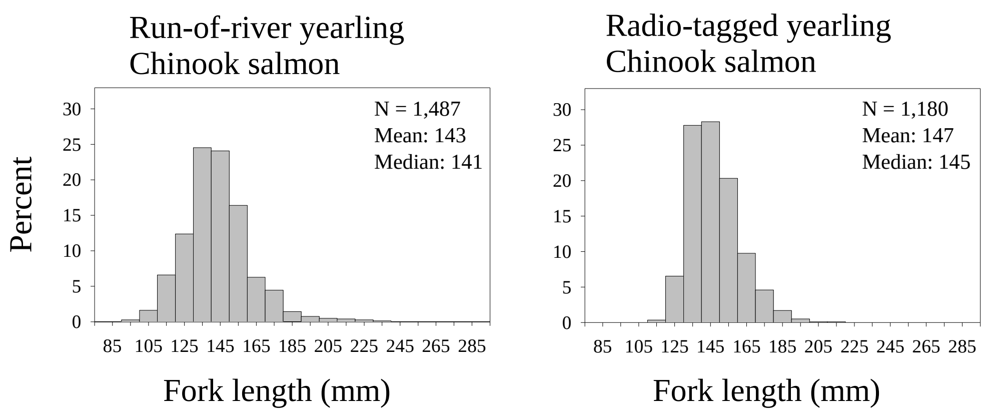

Figure 7. Seasonal (3 May - 2 June) comparison of yearling Chinook salmon fork length frequency distributions at John Day Dam, 2006. The graph on the left depicts run-of-river fish that were sampled at the John Day Dam smolt monitoring facility. The graph on the right depicts fish that were collected at the John Day Dam smolt monitoring facility, tagged with NTC-3-1 radio transmitters (Lotek Engineering, Newmarket, Ontario), and released at The Dalles Dam during 2006.

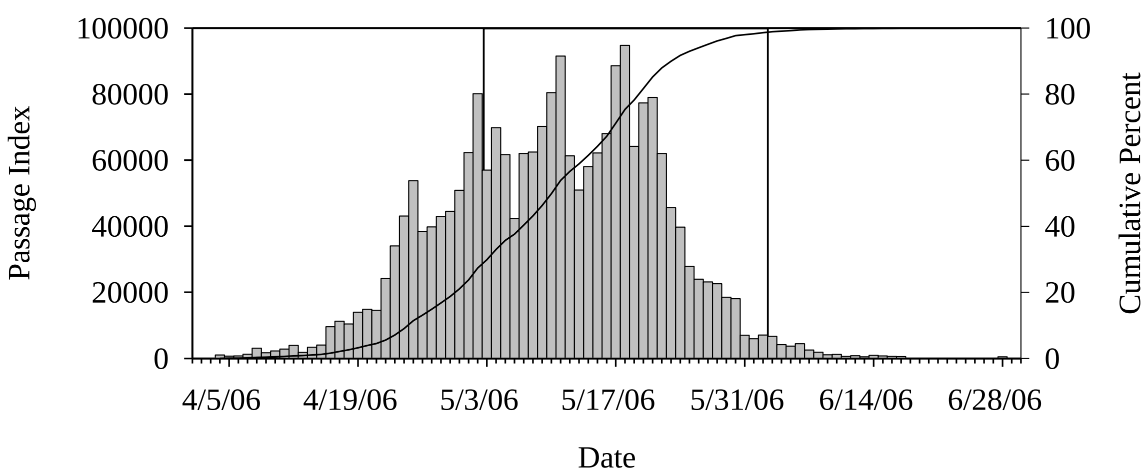

Figure 8. Yearling Chinook salmon passage index at John Day Dam, 2006. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radiotelemetry tagging.

Releases of dead radio-tagged fish

Assumption A7 of release-recapture models used to estimate survival of juvenile salmonids is that the status of the smolt (i.e., alive or dead) is correctly assessed. Dead radio-tagged fish drifting downstream could result in false-positive detections, positively biasing survival estimates. Thus, releases of dead radio-tagged fish were made in the forebay along with the releases of live fish to validate this assumption. No dead radio-tagged yearling Chinook salmon were detected at any of the radiotelemetry arrays downstream of The Dalles Dam.

Fish passage

Of the 1,180 radio-tagged fish released, 848 fish (~72%) were assigned passage at the spillway (Figure 9). The relatively low detection rate at The Dalles Dam spillway in 2006 (72% in 2006 compared to 94-99% in past years) was likely due to the loss of the underwater antenna array between bays 5 and 6 before the study began. After discussing options with the U.S. Army Corps of Engineers, Portland District, the decision was made to proceed with the study without replacement of the array between bays 5 and 6 knowing that detection capabilities would be reduced.

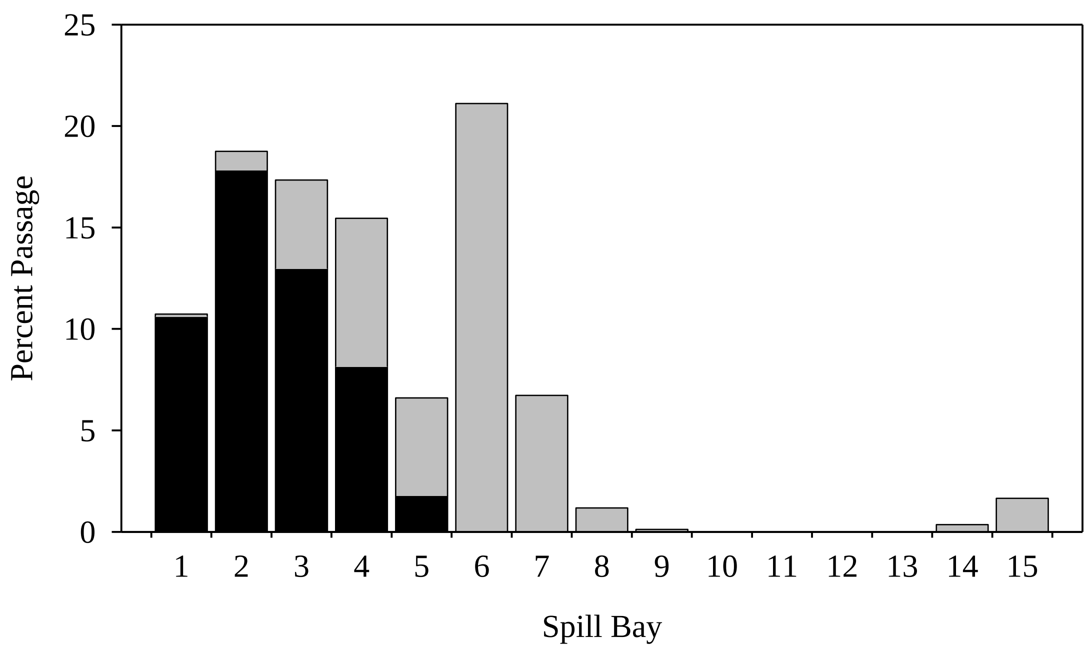

Figure 9. Radio-tagged yearling Chinook salmon passage at The Dalles Dam spillway, 2006. The bars indicate the percent of fish that passed through a particular spill bay. The black shading represents fish released at the north release site, and gray shading represents fish released at the south release site.

Survival estimates

The estimated survival of yearling Chinook salmon passing spill bays 1-4 ranged from 0.910 to 0.979 (Table 1), and averaged 0.946 (SE = 0.010, 95% confidence interval = [0.922 - 0.969]) (Table 1 and Figure 10). The estimated survival for yearling Chinook salmon passing spill bays 5-6 ranged from 0.803 to 0.966 (Table 1), and averaged 0.906 (SE = 0.019, 95% confidence interval [0.863 - 0.949]) (Table 1 and Figure 10). The estimated survival of radio-tagged fish passing bays 1-4 was significantly higher than for fish passing bays 5-6 ($t(14) = 1.87$, $P<0.05$, 1-tailed t-test).

Radiotelemetry survival evaluations of yearling Chinook salmon passing the spillway at The Dalles Dam indicate that survival estimates were higher for fish passing bays 1-4 than through bays 5-6 for all years studied (Figure 10). Survival estimates for 2006 were very similar to 2005, whereas 2004 estimates were relatively low (Figure 10). Single release-recapture survival model estimates were lower than paired release recapture estimates, as is expected due to differences in the models and their associated study designs (Table 2).

Table 1. Radio-tagged yearling Chinook salmon single release model estimated survival probabilities for The Dalles Dam spillway analysis, spring 2006. The analysis blocks (see Table A1.2), spill bay passage groups, sample sizes (for blocks, *N* = number of fish; for overall estimates, *N* = number of blocks), survival probabilities (*S*), standard errors (SE), and profile likelihood 95% confidence intervals are presented.

Block	Passage Group	*N*	*S*	SE	Profile Likelihood 95% CI
1	Bays 1-4	67	0.910	0.035	0.815 - 0.959
	Bays 5-6	29	0.966	0.034	0.792 - 0.995
2	Bays 1-4	65	0.923	0.033	0.828 - 0.968
	Bays 5-6	33	0.939	0.042	0.788 - 0.985
3	Bays 1-4	63	0.968	0.022	0.882 - 0.992
	Bays 5-6	22	0.864	0.073	0.652 - 0.955
4	Bays 1-4	63	0.910	0.037	0.805 - 0.961
	Bays 5-6	40	0.803	0.064	0.650 - 0.899
5	Bays 1-4	62	0.936	0.031	0.840 - 0.976
	Bays 5-6	21	0.905	0.064	0.689 - 0.976
6	Bays 1-4	48	0.979	0.021	0.866 - 0.997
	Bays 5-6	23	0.913	0.059	0.711 - 0.978
7	Bays 1-4	87	0.966	0.020	0.898 - 0.989
	Bays 5-6	20	0.901	0.067	0.676 - 0.975
8	Bays 1-4	73	0.973	0.019	0.897 - 0.993
	Bays 5-6	47	0.957	0.029	0.845 - 0.989
Overall	Bays 1-4	8	0.946	0.010	0.922 - 0.969*
	Bays 5-6	8	0.906	0.019	0.863 - 0.949*

* - 95% confidence interval

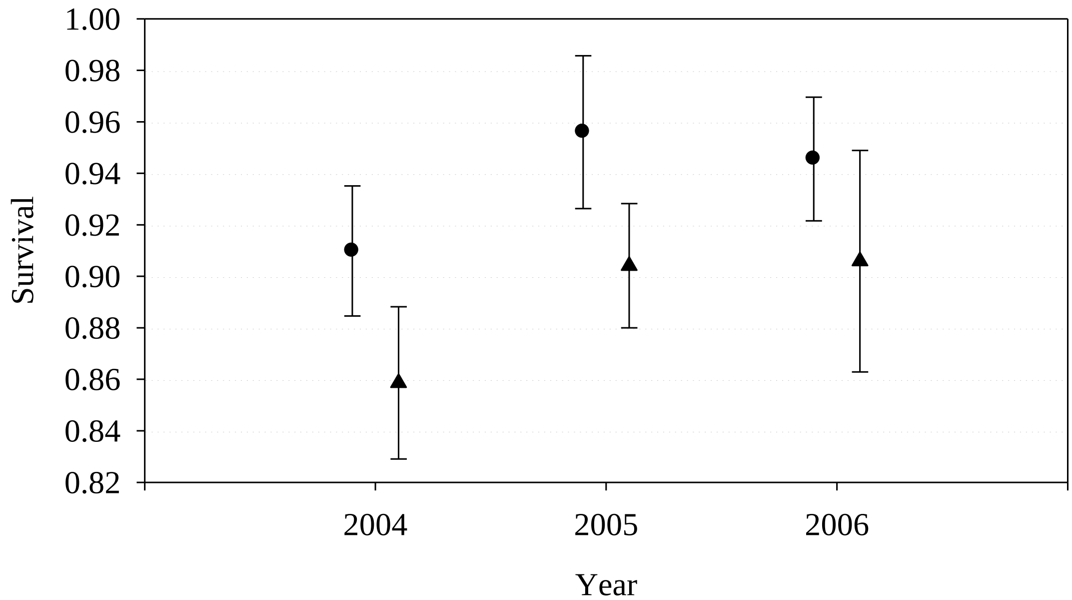

Figure 10. Single release-recapture model survival estimates for radio-tagged yearling Chinook salmon passing spill bays 1-4 (circles) or spill bays 5-6 (triangles) at The Dalles Dam spillway in 2004, 2005, and 2006. Error bars represent 95% confidence intervals.

Table 2. Single release-recapture model and paired release-recapture model survival estimates for radio-tagged yearling Chinook salmon passing spill bays 1-4 or spill bays 5-6 at The Dalles Dam spillway in 2004, 2005, and 2006. Survival probabilities (*S*), standard errors (SE), and 95% confidence intervals are presented.

	Spill bays 1-4			Spill bays 5-6		
	S	SE	95% CI	*S*	SE	95% CI
2004 Single release	0.910	0.012	0.885 - 0.935	0.859	0.014	0.829 - 0.888
2004 Paired release	0.933	0.014	0.906 - 0.960	0.894	0.014	0.866 - 0.922
2005 Single release	0.956	0.014	0.926 - 0.986	0.904	0.011	0.880 - 0.928
2005 Paired release	0.967	0.017	0.931 - 1.003	0.933	0.016	0.899 - 0.966
2006 Single release	0.946	0.010	0.922 - 0.969	0.906	0.019	0.863 - 0.949

Spillway egress

Of the 763 yearling Chinook salmon that were assigned passage through spill bays 1-6, 651 were detected at the basin island exit (1.7 km downriver). Fish that passed through spill bays 1-4 had significantly faster travel times to the exit site (P<0.0001). The median travel time of fish that passed through spill bays 1-4 (10.6 min) was 30% faster than the median travel time of fish that passed through spill bays 5-6 (15.1 min) to the basin island exit (Table 3). In 2005, the median travel time to the basin island exit for radio-tagged fish passing bays 1-4 was faster than for bays 5-6 (Daniel et al. 2006). However, travel times in 2005 were more than two times longer than in 2006 (Figure 11).

Table 3. Radio-tagged yearling Chinook salmon egress times to the basin island exit station, spring 2006. The analysis blocks (see Table A1.2), spill bay passage groups, sample sizes (N = number of fish), and median, minimum, and maximum egress times are presented.

			Egress Time (min)		
Block	Passage Group	N	Median	Minimum	Maximum
1	Bays 1-4	61	10.6	4.6	17.8
	Bays 5-6	27	18.7	8.0	136.7
2	Bays 1-4	56	12.1	5.3	203.5
	Bays 5-6	29	18.2	10.7	385.8
3	Bays 1-4	51	12.3	7.5	29.8
	Bays 5-6	20	20.4	10.0	145.2
4	Bays 1-4	48	12.9	6.4	35.7
	Bays 5-6	31	20.0	9.9	56.2
5	Bays 1-4	52	9.7	6.3	16.1
	Bays 5-6	19	12.0	9.7	21.5
6	Bays 1-4	39	9.3	6.9	21.7
	Bays 5-6	20	11.4	8.1	109.8
7	Bays 1-4	70	9.2	6.0	18.6
	Bays 5-6	17	11.4	6.5	14.2
8	Bays 1-4	67	9.6	6.2	18.3
	Bays 5-6	44	14.7	7.7	38.7
Overall	Bays 1-4	444	10.6	4.6	203.5
	Bays 5-6	207	15.1	6.5	385.8

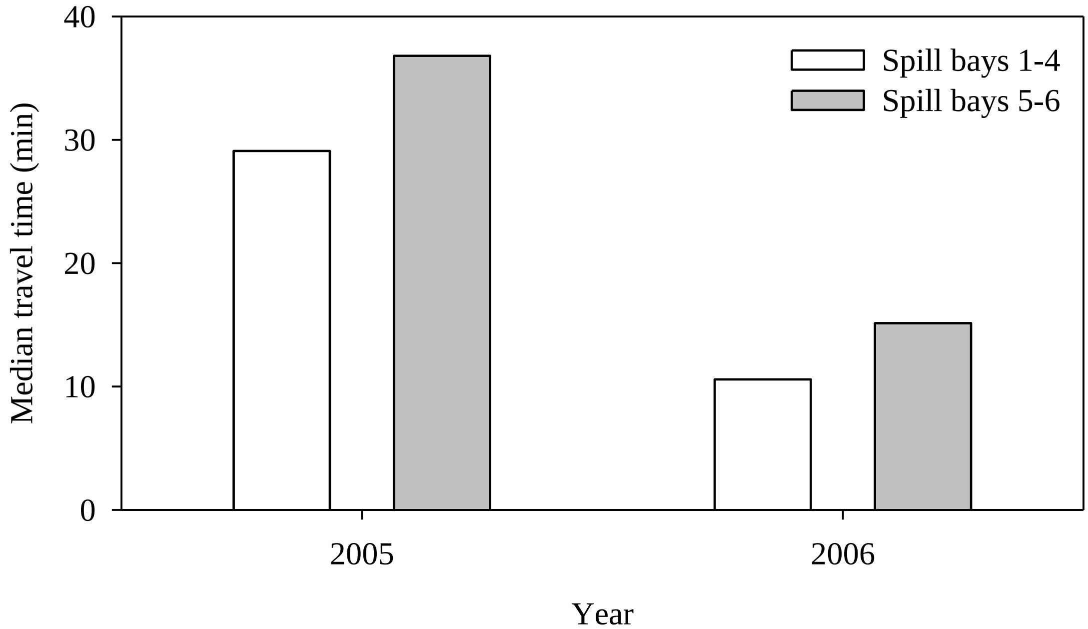

Figure 11. Radio-tagged yearling Chinook salmon median egress times to the basin island exit.

Eddy residence

Of the 763 yearling Chinook salmon assigned passage through spill bays 1-6, 648 (85%) were detected on the fixed receiving station monitoring the eddy located along the navigation lock wall. There were 221 radio-tagged fish detected by the eddy array for greater than 5 min that passed through the north channel, with 42.1% being fish that passed through the spill bays 1-4 and 57.9% being fish that passed through spill bays 5-6. The median residence time in the eddy of fish that passed through spill bays 1-4 (6.8 min) was significantly shorter than for fish that passed through spill bays 5-6 (8.5 min; P = 0.001; Table 4).

Table 4. Radio-tagged yearling Chinook salmon residence times in the navigation lock eddy, spring 2006. The analysis blocks (see Table A1.2), spill bay passage groups, sample sizes (*N* = number of fish), and median, minimum, and maximum residence times are presented. Data are for fish detected for longer than 5 min, and passing through the north channel.

Block	Passage Group	*N*	Residence Time (min) Median	Minimum	Maximum
1	Bays 1-4	10	6.1	5.1	137.6
	Bays 5-6	6	12.7	5.3	119.8
2	Bays 1-4	18	7.7	5.2	208.2
	Bays 5-6	25	10.8	5.4	1415.1
3	Bays 1-4	13	11.5	5.3	27.4
	Bays 5-6	14	9.1	5.2	70.3
4	Bays 1-4	14	7.1	5.1	18.9
	Bays 5-6	25	11.1	5.4	26.4
5	Bays 1-4	8	6.6	5.6	60.7
	Bays 5-6	13	6.4	5.1	23.4
6	Bays 1-4	4	6.7	5.4	760.6
	Bays 5-6	6	7.6	6.1	25.1
7	Bays 1-4	9	6.1	5.4	49.6
	Bays 5-6	8	5.8	5.1	12.8
8	Bays 1-4	17	5.7	5.1	16.1
	Bays 5-6	31	7.8	5.6	17.0
Overall	Bays 1-4	93	6.8	5.1	760.6
	Bays 5-6	128	8.5	5.1	1415.1

South stilling basin residence time

Of the 763 yearling Chinook salmon that were assigned passage through spill bays 1-6, 50 (7%) were detected south of the spillwall within the stilling basin, upstream of the Route 197 Bridge. The majority (68%) of these fish passed through the south spillway, specifically bay 6 (Table 5). The incidence of detection south of the spillwall was lowest for fish that passed through bay 1 and highest for fish that passed through bay 6. The median residence time south of the spillwall for fish that passed through bays 1-4 (1.5 min) was significantly shorter than for fish that passed through bays 5-6 (5.4 min; $P = 0.002$; Table 5). The longest residence time south of the spillway was for a fish that passed bay 6, was in the stilling basin south of the spillwall for about 7.5 h, and then continued downriver with a series of detections at reservoir stations. For fish detected within the stilling basin, ten (1.3% of total) passed the bridge through the south channel. Of these fish, one passed through bay 3, one passed through bay 5, and eight passed through bay 6.

Table 5. Radio-tagged yearling Chinook salmon residence times in the stilling basin, south of the spillwall. Residence time was calculated from last forebay detection to first detection on the Route 197 Bridge array. The spill bay of passage, number (*N*) of fish detected, percent of fish detected, and median, minimum, and maximum residences times are presented.

Passage Bay	*N* Detected	% Detected	Residence Time (min)		
			Median	Minimum	Maximum
1	1	2 %	2.7	2.7	2.7
2	2	4 %	1.1	1.0	1.1
3	4	8 %	1.4	1.4	1.5
4	9	18 %	1.7	0.7	70.5
5	5	10 %	2.5	0.8	10.9
6	29	58 %	5.7	0.8	458.9
Bays 1 - 4	16	32 %	1.5	0.7	70.5
Bays 5 - 6	34	68 %	5.4	0.8	458.9
Overall	50		2.6	0.7	458.9

Discussion

USGS radiotelemetry survival evaluations of yearling Chinook salmon passing the spillway at The Dalles Dam in 2004, 2005, and 2006 indicate that survival estimates were higher for fish passing through spill bays 1-4 than through spill bays 5-6 (Figure 10). The lower survival of fish passing bays 5-6 may be due the severe hydraulic conditions of a large vortex that forms in the forebay on the south side of spill bay 6. Strong surface flows associated with the vortex could entrain fish migrating through spill bay 6. The survival estimates generated in the USGS radiotelemetry studies incorporate all sources of mortality, both direct (e.g., instantaneous mortality, injury) and indirect (e.g., predation, disease). Studies examining direct sources of mortality using balloon tags at The Dalles Dam spillway in 2004 found that survival estimates were higher and passage related maladies were lower for yearling Chinook salmon passing spill bays 2 and 4 than for spill bay 6 (Normandeau Associates, Inc. and Skalski 2005). In contrast to 2004, a 2006 balloon tag study at The Dalles Dam spillway found similar survival probabilities and injury rates for fish passing spill bay 4, spill bay 6, and the spill bay 6 vortex. Contrary to the null hypothesis, estimates of fish without maladies (i.e. visible injuries or loss of equilibrium) were higher for fish passing through spill bay 6 than for spill bay 4 (Normandeau Associates, Inc. and Skalski 2007). Higher survival estimates for spill bay 6 vortex passed fish in 2006 compared to 2004 were attributed to reduced predation thought to be due to lower water temperatures, higher river and spillway flows, and post-passage dispersal of juvenile salmon towards the thalweg. Taken together, the results of the radiotelemetry and balloon-tag studies suggest that processes downstream of the spillway stilling basin have a marked effect on survival.

Median travel time to the basin island exit for radio-tagged fish passing through spill bays 1-4 was significantly faster than for fish passing spill bays 5-6 in both 2005 and 2006 (Figure 11). Due to higher flows in 2006, travel times were more than twice as fast as they were in 2005, yet survival probabilities were similar between the two years (Figures 11 and 10). During 2005, a mobile tracking study at The Dalles Dam spillway found that fish passing spill bays 5-6 were frequently delayed in slow moving water south of the thalweg below the bridge island, whereas fish passing spill bays 1-4 were more likely to travel in or near the faster moving waters of the thalweg (Daniel et al. 2006).

Fish passing through both spill bays 1-4 and spill bays 5-6 were detected at the fixed receiving station monitoring the navigation lock eddy and arrays monitoring the stilling basin south of the spillwall. Both of these areas were monitored to improve our understanding of egress routes within the stilling basin and to better assess the potential for delayed egress and corresponding additional risk of predation. The percent of fish detected by the navigation lock eddy array was highest and the residence time was longest for fish that passed through spill bays 5-6. This finding was counterintuitive in that the eddy is immediately downriver of spill bay 1. Fish passing spill bays 5-6 either moved northward into the eddy, or it is possible that if fish were near enough to the surface they could have been detected by the eddy array even if they weren't actually in the eddy. Although the residence time within the detection range of the eddy array was significantly longer for fish passing through spill bays 5-6 than for fish passing through spill bays 1-4, the difference was nominal (1.7 min). Median residence times for fish detected at the navigation lock eddy (7 - 9 min) were approximately half of the median tailrace egress times (11 – 15 min), suggesting that the eddy represented a limited additional risk of predation to these fish.

The arrays monitoring the stilling basin south of the spillwall detected 7% of radio-tagged fish that passed through spill bays 1-6. Fish that passed through bay 6 comprised a majority of the fish detected south of the spillwall, and had the longest residence times within the area. The median residence times south of the spillwall were between 1 and 6 min, and therefore did not represent a large delay in tailrace egress by yearling Chinook salmon. Both the navigation lock eddy and the area south of the spillwall are areas of concern for egress and may warrant further investigation with respect to potential predation losses.

The cause of the lower survival of fish passing through spill bays 5-6 compared to 1-4 remains uncertain. Environmental and hydraulic conditions coupled with the location of passage through a spill bay (e.g., vortex passage) may affect fish condition and subsequent survival. The results of recent egress studies suggest that travel paths of fish moving through the tailrace have a larger effect on survival than absolute travel rates. The distribution of predators likely changes with operational and structural changes to the dam. Predation risk associated with various travel paths could be better understood by investigating predator distributions concurrently with juvenile survival and egress studies.

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Appendix A: Release Dates, Times, Fork lengths, and Weights

Table A1.1. Summary of yearling Chinook salmon releases at The Dalles Dam forebay during spring 2006. Dates, times, numbers of tagged fish released (*N*), release site, and means, standard deviations (SD) and ranges for fork lengths and weights are presented.

					Fork Length (mm)			Weight (g)		
Release	Date	Time	Site	*N*	Mean	SD	Range	Mean	SD	Range
1	3-May	1:27	North	18	150.2	12.4	135 - 175	33.8	8.7	23.1 - 53.1
2	3-May	1:35	South	18	157.1	16.6	130 - 185	38.7	11.8	17.5 - 55.6
3	3-May	13:04	North	18	156.3	16.4	130 - 198	36.6	13.6	21.5 - 80.1
4	3-May	13:11	South	19	159.4	21.2	135 - 193	41.6	17.0	22.3 - 74.0
5	4-May	7:11	North	19	151.2	18.3	126 - 190	34.3	12.5	18.6 - 63.2
6	4-May	7:17	South	18	152.6	13.2	120 - 177	35.3	9.0	16.7 - 55.7
7	5-May	19:09	North	19	145.5	12.3	125 - 170	30.7	7.6	20.1 - 46.1
8	5-May	19:03	South	18	143.7	7.3	135 - 160	28.9	5.0	22.1 - 39.0
9	6-May	12:59	North	19	148.2	11.9	130 - 173	32.5	8.7	22.5 - 54.4
10	6-May	13:05	South	18	152.2	12.1	131 - 172	34.7	8.2	22.5 - 50.1
11	7-May	7:08	North	18	141.3	12.0	120 - 169	28.6	6.9	18.5 - 46.3
12	7-May	7:03	South	19	146.3	12.3	132 - 182	30.7	9.2	22.1 - 62.5
13	9-May	1:05	North	19	145.1	17.3	123 - 180	30.9	10.6	21.2 - 53.5
14	9-May	1:10	South	18	148.3	18.2	122 - 189	34.2	15.0	20.3 - 74.7
15	9-May	19:11	North	18	152.7	18.3	130 - 190	33.9	12.8	20.3 - 61.5
16	9-May	19:16	South	19	152.1	14.1	126 - 176	34.9	9.4	20.5 - 50.8
17	10-May	7:07	North	18	156.2	18.4	127 - 182	38.6	12.4	20.9 - 59.6
18	10-May	7:13	South	18	142.1	13.7	127 - 168	29.3	8.5	20.4 - 46.2
19	11-May	19:26	North	19	148.7	15.3	122 - 179	31.8	10.8	18.6 - 53.0
20	11-May	19:30	South	18	149.1	15.2	129 - 180	33.4	11.0	22.2 - 57.3
21	12-May	19:26	North	18	148.4	11.7	125 - 172	29.4	6.9	17.5 - 42.7
22	12-May	19:23	South	19	151.0	13.2	129 - 172	33.7	9.7	19.1 - 54.2

Table A1.1. Continued.

Release	Date	Time	Site	*N*	Fork Length (mm)			Weight (g)		
					Mean	SD	Range	Mean	SD	Range
23	13-May	13:14	North	18	151.7	10.6	135 - 170	31.4	6.7	22.5 - 46.1
24	13-May	13:22	South	15	148.6	13.3	130 - 175	31.6	8.2	21.5 - 50.5
25	14-May	19:14	North	19	143.2	12.3	124 - 165	28.1	8.0	16.6 - 46.8
26	14-May	19:18	South	18	137.1	10.3	115 - 150	25.0	5.6	14.5 - 32.9
27	15-May	12:57	North	19	145.1	7.9	130 - 162	28.1	5.2	17.9 - 40.0
28	15-May	13:02	South	18	143.3	11.1	126 - 170	28.5	6.6	17.9 - 42.7
29	16-May	7:49	North	18	139.7	11.2	124 - 167	26.1	6.7	16.3 - 43.0
30	16-May	7:53	South	19	144.1	14.1	120 - 174	29.3	8.9	17.1 - 50.4
31	18-May	1:17	North	17	145.9	12.0	125 - 169	30.1	7.7	18.0 - 45.8
32	18-May	1:21	South	19	147.6	10.9	131 - 179	31.5	6.9	22.9 - 52.5
33	19-May	1:10	North	18	142.9	7.7	130 - 156	28.9	5.6	20.7 - 39.5
34	19-May	1:14	South	19	149.0	10.1	133 - 173	32.2	7.0	21.8 - 48.9
35	19-May	7:36	North	18	144.8	12.2	127 - 170	28.9	8.2	18.8 - 47.1
36	19-May	7:42	South	19	146.9	12.3	126 - 172	30.0	8.6	18.9 - 47.8
37	20-May	19:00	North	19	148.9	16.8	121 - 194	32.9	11.7	19.0 - 66.8
38	20-May	19:04	South	18	142.6	12.7	123 - 167	28.7	7.6	18.8 - 45.1
39	21-May	13:10	North	19	140.2	7.6	129 - 155	25.6	4.1	19.2 - 34.8
40	21-May	13:15	South	18	141.8	11.7	130 - 179	26.5	8.4	18.7 - 53.7
41	23-May	1:05	North	17	145.4	14.7	129 - 189	28.7	10.1	20.8 - 58.8
42	23-May	1:08	South	20	145.5	13.7	128 - 175	28.9	9.8	18.6 - 53.4
43	23-May	13:04	North	20	148.0	13.6	128 - 173	30.2	10.1	18.7 - 53.9
44	23-May	13:01	South	19	144.6	9.3	133 - 168	27.5	6.5	19.5 - 42.4

Table A1.1. Continued.

Release	Date	Time	Site	*N*	Fork Length (mm) Mean	SD	Range	Weight (g) Mean	SD	Range
45	24-May	7:09	North	19	145.6	15.0	122 - 186	28.9	9.0	17.3 - 55.4
46	24-May	7:14	South	20	139.5	12.9	113 - 169	24.9	7.6	16.8 - 44.2
47	25-May	19:04	North	18	140.7	11.8	124 - 163	26.9	7.8	16.6 - 46.0
48	25-May	19:00	South	19	138.3	9.1	118 - 157	26.3	5.5	14.9 - 37.5
49	26-May	13:09	North	18	138.6	8.0	125 - 158	26.4	6.0	18.9 - 43.7
50	26-May	13:14	South	19	142.9	9.9	129 - 165	27.4	6.4	18.3 - 43.6
51	27-May	19:28	North	20	145.0	10.8	124 - 160	28.6	6.3	18.5 - 43.2
52	27-May	19:25	South	18	143.7	13.9	121 - 165	27.8	7.6	15.0 - 41.3
53	29-May	1:16	North	20	138.5	6.3	128 - 150	25.1	3.9	19.7 - 33.1
54	29-May	1:13	South	18	140.9	10.2	126 - 160	26.9	6.4	17.6 - 35.9
55	29-May	7:03	North	18	140.5	9.7	128 - 162	27.8	6.1	19.8 - 43.8
56	29-May	7:08	South	19	146.9	9.8	120 - 158	31.6	5.8	18.9 - 39.8
57	30-May	19:25	North	18	141.1	13.4	120 - 169	29.6	8.7	18.7 - 54.0
58	30-May	19:28	South	19	147.3	9.8	126 - 163	32.2	6.3	21.3 - 42.7
59	31-May	7:01	North	18	149.3	16.6	124 - 184	32.2	10.6	19.0 - 57.6
60	31-May	7:04	South	19	145.8	18.4	118 - 202	31.6	12.1	15.8 - 70.7
61	2-Jun	1:17	North	16	149.6	11.5	128 - 165	33.4	7.5	20.9 - 46.9
62	2-Jun	1:13	South	18	153.4	20.0	130 - 210	35.3	15.8	20.8 - 85.3
63	2-Jun	13:09	North	19	153.9	13.8	126 - 181	36.4	10.4	18.7 - 56.5
64	2-Jun	13:13	South	18	149.8	11.8	120 - 162	32.8	7.1	16.5 - 40.3
North				589	146.3	13.7	120 - 198	30.4	9.2	16.3 - 80.1
South				591	146.6	13.9	113 - 210	31.0	9.7	14.5 - 85.3
Overall				1180	146.5	13.8	113 - 210	30.7	9.5	14.5 - 85.3

Table A1.2. Summary of yearling Chinook salmon analysis blocks for The Dalles Dam spillway survival analysis, spring 2006. The releases constituting the analysis blocks (see Table A1.1), the spill bay passage group, number of fish (*N*), and means, standard deviations (SD) and ranges for fork lengths and weights are presented.

				Fork Length (mm)			Weight (g)		
Block	Releases	Passage group	*N*	Mean	SD	Range	Mean	SD	Range
1	1 - 8	Bays 1-4	67	150.7	13.8	126 - 190	33.8	9.5	18.6 - 63.2
		Bays 5-6	29	151.6	17.0	130 - 193	34.4	13.0	17.5 - 74.0
2	9 - 16	Bays 1-4	65	149.3	16.3	123 - 190	33.1	11.0	20.3 - 63.9
		Bays 5-6	33	148.9	16.2	122 - 189	33.7	12.6	20.3 - 74.7
3	17 - 24	Bays 1-4	63	152.2	12.8	125 - 181	33.5	9.2	17.5 - 57.3
		Bays 5-6	22	146.5	13.5	127 - 175	30.8	8.8	21.0 - 50.5
4	25 - 32	Bays 1-4	63	144.1	11.1	115 - 174	28.5	7.1	14.5 - 50.4
		Bays 5-6	40	142.8	11.3	120 - 170	28.3	6.9	16.4 - 45.8
5	33 - 40	Bays 1-4	62	143.5	10.7	121 - 170	28.6	7.3	18.8 - 50.6
		Bays 5-6	21	146.5	11.2	127 - 166	30.2	7.9	18.9 - 47.8
6	41 - 48	Bays 1-4	48	143.2	14.8	118 - 189	28.0	9.0	14.9 - 58.8
		Bays 5-6	23	143.0	12.7	113 - 173	27.4	7.8	16.8 - 49.6
7	49 - 56	Bays 1-4	87	141.3	9.9	124 - 165	27.1	6.0	17.6 - 43.8
		Bays 5-6	20	142.2	10.4	128 - 165	27.0	6.4	18.5 - 43.6
8	57 - 64	Bays 1-4	73	148.6	14.3	120 - 184	32.8	9.5	18.7 - 57.6
		Bays 5-6	47	148.0	16.3	118 - 210	32.4	11.9	15.8 - 85.3
Overall	1 - 64	Bays 1-4	528	146.6	13.5	115 - 190	30.7	9.0	14.5 - 63.9
		Bays 5-6	235	146.4	14.3	113 - 210	30.9	10.3	15.8 - 85.3

Appendix B: Study Summary

Year	2006
Study Site	The Dalles Dam
Objectives	Evaluate single release model survival estimates and characterize tailrace egress for radio-tagged yearling Chinook salmon that passed through spill bays 1-4 or 5-6 to assess the efficacy of the spillway modifications.
Fish species and source	Hatchery yearling Chinook Salmon collected from John Day smolt monitoring facility

Fish size — Yearling Chinook salmon

	Length (mm)	Weight (g)
Min	113	14.5
Max	210	85.3
Mean	146.5	30.7
Median	145	28.5

Tag

Type	Lotek Engineering, Radio tag
Model	NTC-3-1
Weight (g, in air)	0.64

Tag procedure	Surgically implanted

Single release survival model estimates for yearling Chinook salmon

	Survival	SE	Total # of fish	# of releases
Spill bays 1-4	0.946	0.010	528	32
Spill bays 5-6	0.906	0.019	235	32

Egress times to the basin island exit site (~1.7 km downstream of the spillway)

	Egress median (min)	Egress range (min)	Total # of fish	# of releases
Spill bays 1-4	10.6	4.6 - 203.5	444	32
Spill bays 5-6	15.1	6.5 - 385.8	207	32

Environmental/ Operating conditions

	mean	range
Avg. daily temperature (°C)	13.2	11.2 - 15.1
Avg. hourly total discharge (kcfs)	328	196 - 409
Avg. hourly spill discharge (kcfs)	131	78 - 251
Avg. hourly spill discharge (%)	40	29 - 66